AMENDED SPECIFICATION

Reprinted as amended in accordance with the decision of the Supervising Examiner acting for the Comptroller-General, dated the twenty-first day of January, 1936, under Section 21 of the Patents and Designs Acts, 1907 to 1932.

(The Amendments are shown in erased and italic type.)

PATENT SPECIFICATION

Application Date: Nov. 17, 1934. No. 32159/34. **435,656***

Complete Specification Left: Feb. 12, 1935.

Accepted: Sept. 25, 1935.

PROVISIONAL SPECIFICATION (AMENDED)

Improvements in or relating to Malleable Iron, and to Grey Cast Iron

We, CRANE LIMITED, a British Company, of 45 to 51, Leman Street, London, E.1, and HORACE HENRY SHEPHERD, a British Subject, of 146, Nacton Road, Ipswich, do hereby declare the nature of this invention to be as follows:—

This invention relates to the manufacture of iron castings, especially malleable cast iron, and in particular to a process with modifications whereby the physical properties of the iron are improved.

The invention is applicable to malleable iron manufactured by different methods, including those known in the art as the blackheart process and commonly called American malleable iron, and that which is known as whiteheart malleable iron, and the object of the invention is to improve the tensile and torsional strength, increase the yield point and elongation properties and to provide malleable iron having improved corrosion-resisting qualities.

The invention is also applicable to the production of high strength grey cast iron and semi-malleable iron by the treatment, hereinafter described, of metal having a composition suitable for the production of malleable iron, so as to produce such grey cast iron and semi-malleable iron by direct treatment in the first case without heat treatment, or subsequent heat treatment, in both cases.

The heat treatment involves short-heat treatment at various temperatures above the ~~re~~calescence point Ac_1 and followed in some instances by tempering or drawing at temperatures varying from 400 to 700° C.

The invention consists in adding copper and titanium, with or without aluminium, to white cast iron of such general composition as is used for the production of malleable irons. The proportions of these additions may vary but, for example, they may be

Copper 0.25 to 3.0 per cent by weight,
Titanium 0.05 to 0.5 per cent by weight,
and if used, Aluminium 0.05 to 0.15 per cent. by weight.

The additions can be made in the case of copper and aluminium, in their single unalloyed state or in the form of alloys and titanium in the form of such alloys as ferro-titanium, copper-titanium-aluminium alloys or titanium-aluminium alloys.

The amounts of metals or alloy additions and the basic composition of the white cast iron are varied to prevent the formation of primary graphite in the castings, in the "as cast" condition, required for the production of malleable castings, and in the case of grey cast iron and "semi"-malleable, as previously described, to cause the primary graphite to exist in a very fine state.

The selected metals are together added to the metal of such composition as would solidify to a white cast iron under ordinary conditions, without any addition, and as would be suitable in this condition for the production of malleable castings.

Our experiments show that the treated metal of such composition as to produce American malleable iron, can be made by shorter heat-treatment, or annealing and/or at lower temperature than is usually necessary.

It is known that the addition of copper to malleable iron raises its tensile strength and increases its resistance to corrosion but it reduces the elongation value. We have found that if appropriate percentages of titanium are added to the metal with the copper, and in some cases

with aluminium, a malleable iron is produced after suitable annealing or heat-treatment, which possesses the benefits of copper additions and further does not suffer loss in the properties as expressed by elongation but may provide a considerable increase in this property over that obtained from ordinary malleable iron.

With higher percentage additions of copper and titanium (according to composition of the base metal) tensile strength may be increased by say 10 to 20% (or more) and elongation maintained or increased.

The results of our experiments show that the structure resulting from such additions as previously set out is of very fine grain in the malleable, grey cast, or semi-malleable iron, which is of special importance in the manufacture of pressure-tested castings; further, that as with copper, titanium increases the rate of graphitisation during annealing and that the combination of copper and titanium further assists, enabling malleablising or annealing to be completed at lower temperatures or in shorter time, and in some cases at both lower temperature and shorter time and some modification of the usual annealing cycle is desirable.

The addition of titanium in the cases of grey cast iron and "semi"-malleable iron counteracts any tendency of the copper to coarsen the primary graphite; and the very fine grained structure obtained renders the metal particularly suitable for heat-treatment.

Dated this 8th day of November, 1934.
HY. FAIRBROTHER,
Chartered Patent Agent,
30 & 32, Ludgate Hill, London.

COMPLETE SPECIFICATION (AMENDED)

Improvements in or relating to Malleable Iron, and to Grey Cast Iron

We, CRANE LIMITED, a British Company, of 45 to 51, Leman Street, London, E.1, and HORACE HENRY SHEPHERD, a British Subject, of 146, Nacton Road, Ipswich, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to the manufacture of malleable cast iron and grey cast iron whereby the physical properties of the irons are improved.

The invention is applicable to malleable cast iron manufactured by different methods, including that known in the art as the blackheart process, and that known as the whiteheart process. The object of the invention is to improve the tensile and torsional strength of the iron, increase the yield point and elongation properties and to provide malleable cast iron having improved homogeneity and better corrosion-resisting qualities.

The invention is also applicable to the production of high strength grey cast iron and semi-malleable cast iron (i.e. cast iron having ductile properties intermediate between those of grey cast iron and ordinary malleable cast iron), by using as a base, metal suited to the production of malleable cast iron and making additions as hereinafter described, so as to produce a grey cast iron or an iron which becomes grey and machineable by subsequent heat treatment, such treatment being shorter than that required for ordinary malleable cast iron in the normal annealing process.

According to the invention there is produced malleable cast iron having improved physical properties, i.e., tensile, *ductility* ~~ductile~~, yield point, elongation and *torsion* ~~tension~~ values and resistance to corrosion, by a process which consists in the addition of copper, titanium and, *optionally* ~~preferably~~, aluminium to white cast iron.

Also according to the invention there is produced malleable cast iron having increased resistance to corrosion over that of ordinary malleable cast iron by a process according to which copper, titanium and, *optionally* ~~preferably~~, aluminium are added in varying amounts to cast iron suitable in composition for the production of malleable cast iron.

The copper and titanium is added conjointly, with or without aluminium, to cast iron of such composition as is used for the production of malleable cast iron. The proportion of the constituents may vary according to the composition of the base metal and the section of the article to be cast, but preferably lies within the following range:—

Copper 0.25 to 3.0 per cent by weight,
Titanium 0.05 to 0.5 per cent by weight,
and optionally, Aluminium 0.015 to 0.15 per cent. by weight.

The additions in the cases of copper and aluminium are made either severally,

in their single unalloyed state, or, combined in the form of alloys. The titanium can be added in the form of an alloy such as ferro-titanium or ferro-titanium-aluminium, or ferro-titanium-copper, or titanium-aluminium. Alternatively, the addition can be made by an alloy of ferro-titanium - copper - aluminium. Alternatively, copper may be incorporated as one of the constituents of the furnace charge.

For the production of malleable cast iron it is well known that it is necessary to prevent the formation of primary graphite and, hence, to cast an iron white in the cast state. In order to do this when the above additions are employed the composition of the base metal must be adjusted, particularly by reducing either the silicon content or the carbon content, or both these elements, by ways well known to metallurgists. Such an iron requires a normal or only slightly modified malleable annealing. For the production of high strength grey cast iron from a white, mottled or grey cast iron, it is necessary to encourage the formation of primary graphite, and in order to do this when the above additions are employed the composition of the base metal must be adjusted either by maintaining or increasing the silicon content or the carbon content, or both these elements. Such irons are machineable in the cast state without annealing. Intermediately, mottled irons may be produced which have small quantities of primary graphite in the cast state, in an otherwise white iron, and which can be converted to grey and machineable iron by a heat treatment process which, however, is of much shorter duration than that normally required for the annealing of ordinary malleable cast iron. The precise compositions of base metal, additions of copper, titanium and aluminium, and annealing time and temperature are dependent to some extent on the section of the article to be cast.

It is well known in malleable foundry practice that the amounts of silicon or carbon or both (but more commonly the silicon) must be varied somewhat according to the sectional thickness of the casting, that is, a thin casting of say 1/4" section can be higher in silicon than a casting of 1" section without the danger of primary graphite forming as referred to above. Now, copper acts in a somewhat similar way to silicon in promoting primary graphite, therefore, when copper additions are made, the silicon contents must be reduced by 0.07% to 0.1% for each 0.5% of copper added.

Titanium is much more powerful in its graphitising action than copper and, therefore, the silicon content suitable for producing any particular sized malleable casting by the ordinary process must be reduced when it is required to produce similar castings in improved malleable cast iron by adding copper and titanium together according to the invention. We find that this reduction of silicon or the silicon equivalent of, for example, the addition of 0.5% copper and 0.05% titanium, is approximately equal to 0.2% silicon. For the same reason it is possible to add more copper and titanium to thinner castings without greatly altering their basic composition than it is to heavier section castings, but the examples given above are examples of average practice.

These procedures according to the invention allow the production of ordinary malleable cast iron of properties superior to those now obtained and, alternatively, the same properties with a shorter anneal and/or at a lower temperature, while the grey irons have, whether tested as cast or after a short annealing, by virtue of their finer graphite size, better mechanical properties than grey iron as ordinarily made.

It is known that the addition of copper to malleable iron raises its tensile strength and increases its resistance to corrosion, but reduces its elongation value and hence its ductility. It is also known that titanium and also aluminium refines the structure and promotes primary graphitization in grey and malleable cast iron and, in the case of malleable cast iron, facilitates the dissociation of the carbide in the subsequent annealing process. Our experiments have shown that a combination of copper and titanium and, optionally, aluminium, in the range of proportions stated above, added to white cast iron, gives a malleable cast iron having not only increased tensile strength and increased yield point and resistance to corrosion, but also increased torsion values, elongation and ductility.

For example, with an ordinary cupola-melted blackheart malleable cast iron the tensile strength after annealing for 66 hours at a maximum temperature of 960° C. was 41,000 lbs. per square inch, with an elongation of 8%. With the incorporation of copper and titanium in an otherwise similar metal, the said metal, after being similarly annealed and tested, had a tensile strength of 52,000 lbs. per square inch, and an elongation of 12%. The copper addition in this case was 1.0%, titanium addition 0.07% and aluminium 0.02%. A similar base metal cast mottled by a copper-titanium addition

gave a tensile strength of 48,500 lbs. per square inch, and an elongation of 2% for a heat treatment of two hours at a maximum temperature of 900° C. The copper addition was 2%, the titanium addition 0.1% and the aluminium addition 0.03%. Irons cast mottled by this process require generally a short time heat treatment at a temperature above the ~~re~~calescence temperature Ac_1 and may also be tempered at temperatures from 400° C. to 700° C. A similar base metal, but adjusted to give a silicon content of 1.2% and total carbon of 3.24%, to which 1.0% of copper, 0.25% of titanium and 0.075% aluminium was added, produced a grey cast iron having a tensile strength of 45,000 lbs. per square inch, possessed no ductility as measured by elongation; Brinell hardness values on sections varying from 5/8" to 1.1/8" were 197 to 217, hence the iron was machineable in the " as cast " state.

The results of our experiments show that the structure resulting from additions according to the invention is of very fine grain in the malleable, grey, and semi-malleable cast irons, which is of special importance in the manufacture of pressure tested castings.

We are aware of Patent Specification No. 390,687 relating to the manufacture of nitrogenised cast iron alloy articles and claim nothing disclosed in the said Specification.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. In a process for the production of malleable cast iron, semi-malleable cast iron and grey cast iron, the step of adding to white or mottled cast iron 0.25% to 3.0% by weight of copper and 0.05% to 0.5% by weight of titanium, and optionally, 0.015% to 0.15% by weight of aluminium all conjointly.

2. A process according to Claim 1, for the production of malleable cast iron, wherein the silicon content and/or the carbon content of the white cast iron is reduced to prevent the formation of primary graphite.

3. A process according to Claim 1, for the production of grey cast iron or semi-malleable cast iron, wherein the silicon content and/or the carbon content of the white cast iron is maintained or increased to encourage the formation of primary graphite.

4. A process according to Claim 1, wherein the white iron containing small quantities of primary graphite is subjected to a heat treatment process which, however, is of much shorter duration than that normally required for malleable annealing.

5. A process according to any of the preceding claims, wherein the copper is added in its single unalloyed state or is incorporated as one of the constituents of the furnace charge.

6. A process according to any of the preceding claims, wherein the titanium is added in the form of an alloy, for example, ferro-titanium or ferro-titanium-copper.

7. A process according to Claim 1, wherein the aluminium is added in its single unalloyed state.

8. A process according to Claim 1, wherein copper and aluminium are added in the form of a copper aluminium alloy.

9. A process according to Claim 1 wherein titanium and aluminium are added in the form of a ferro-titanium-aluminium alloy or a titanium-aluminium alloy.

10. A process according to Claim 1, wherein copper, titanium and aluminium are added in the form of a ferro-titanium-copper-aluminium alloy.

11. Malleable cast iron and semi-malleable cast iron when produced according to any of Claims 1 and 2, and 5 to 10.

12. Grey cast iron and semi-malleable cast iron when produced by any of Claims 1, and 3 to 10.

13. A process for producing malleable cast iron having improved physical properties i.e., tensile, ~~ductile~~, *ductility*, yield point, elongation and torsion values and resistance to corrosion resulting from additions of copper, titanium and, ~~preferably~~, *optionally* aluminium to white cas iron.

14. A process for producing malleable cast iron having increased resistance to corrosion over that of ordinary malleable cast iron, according to which copper, titanium and, ~~preferably~~, *optionally* aluminium are added in varying amounts to cast iron suitable in composition for the production of malleable cast iron.

15. A process for reducing the time and/or temperature required for the annealing of white iron castings to produce malleable iron castings by the black-heart process according to which copper, titanium and aluminium are added to the metal as set out in Claim 1.

16. A process for making semi-malleable cast iron, according to which copper and titanium and, in some cases aluminium, are added to white iron, so as to produce a mottled iron, i.e., an iron which has small quantities of primary graphite present in the " as cast " state,

and subjected to short heat treatment—very much shorter than ordinary malleable annealing treatment, and shorter than that necessary for annealing such iron as may be produced according to Claim 15.

17. A process for producing high strength grey cast iron by treatment of white or mottled cast iron, by additions of copper, titanium and possibly aluminium, the carbon content or the silicon content, or both being adjusted according to the section of the article to be cast, the amounts varying.

Dated this 12th day of February, 1935.

HY. FAIRBROTHER,
Chartered Patent Agent,
30 and 32, Ludgate Hill, London, E.C.4.

Leamington Spa: Printed for His Majesty's Stationery Office, by the Courier Press.—1936.